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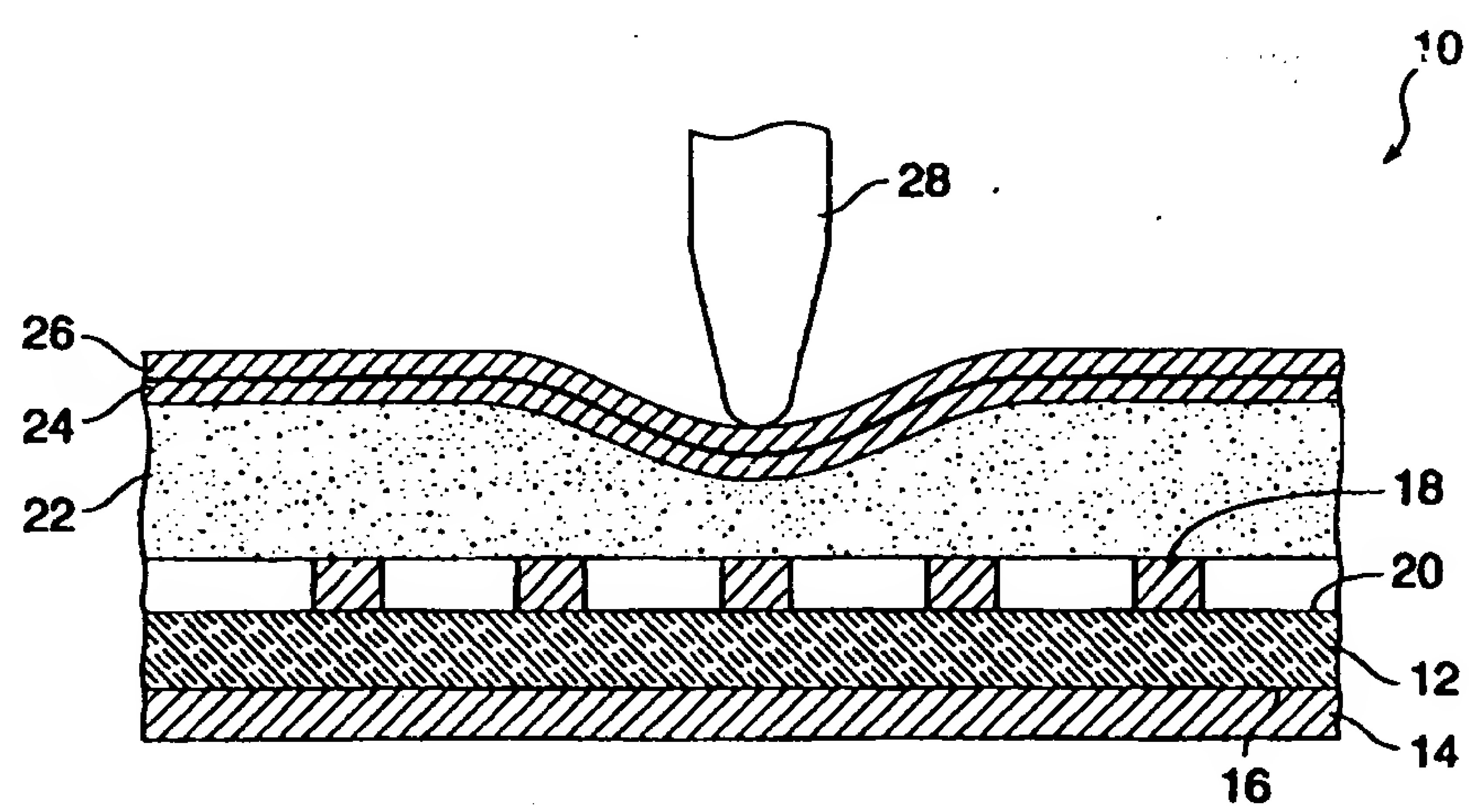
(54) Title: STYLUS INPUT CAPACITIVE TOUCHPAD SENSOR

(57) Abstract

A capacitive sensor comprises first and second sets of conductive traces and a compliant rugose material having a rugose surface located proximate to the first and second sets of conductive traces whereby deformation of the rugose surface causes a change in dielectric constant of the rugose material in the region of the conductive traces.



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SPECIFICATION

STYLUS INPUT CAPACITIVE TOUCHPAD SENSOR

RELATED APPLICATIONS

This application is a continuation-in-part of co-pending application serial No. 08/________, filed October 19, 1995 (Atty Docket No. SYN-066), which is a continuation-in-part of co-pending application serial No. 08/300,387, filed September 2, 1994, which is a continuation-in-part of co-pending application serial No. 08/115,743, filed August 31, 1993, now United States Patent No. 5,374,787, which is a continuation-in-part of co-pending application serial No. 07/895,934, filed June 8, 1992.

BACKGROUND OF THE INVENTION

1. Field Of The Invention

The present invention relates to computers and computer cursor control input devices. More particularly, the present invention relates to a capacitive touch pad suitable for accepting input from a non-conductive stylus.

2. The Prior Art

Capacitive touch sensing devices (touchpads) are currently known in the art and are available from several manufacturers. The principle advantage of capacitive touch technology is sensitivity to fingers. Only very light contact is required to accurately detect the position of a finger on the pad. This feature makes capacitive touch sensors especially suitable as computer pointing devices.

Capacitive sensors have, so far, been limited to detecting conductive objects which create a large area of contact on the pad and have sufficient capacitance to be detected (for example, human fingers). Objects which are either small or not conductive are difficult to detect capacitively because they have very little capacitance. Thus, a plastic stylus or pen cannot be reliably and accurately detected by existing capacitive sensors. This limitation has excluded capacitive touch sensors from applications, such as graphics tablets, which may require pen input.

Resistive touch sensing devices are also well-known in the art, and substantially preceded capacitive touchpads in the market. Most resistive sensing devices require substantial pressure on the surface in order to accurately determine the point of contact. A stylus, which produces a small region of high contact pressure, is easily detected by resistive sensors. A light finger touch is difficult to detect using resistive technology, since the touch force is distributed over a larger area and there is no region of high contact pressure. Resistive technology has been adopted for

applications which allow for greater contact force or do not require much positioning accuracy (e.g. touch screens).

While resistive touch sensing technology has existed for decades, it has never been widely adopted for computer pointing devices. Not until the light touch sensitivity made possible by the recent introduction of capacitive sensors have users accepted touchpads as a preferred input device in computer applications.

It is an object of the present invention to provide a capacitive touchpad which overcomes some of the limitations of the prior art.

It is an object of the present invention to provide a capacitive touchpad which can accept input from a non-conductive stylus.

It is a further object of the present invention to provide a capacitive touchpad which can accept input from a non-conductive stylus or a light finger touch.

BRIEF DESCRIPTION OF THE INVENTION

According to a first embodiment of the present invention, a capacitive touch pad comprises a substrate material, such as a PC board type laminate material, having a plurality of first parallel conductive traces running in a first (X) direction disposed on a first face thereof, and a plurality of second parallel conductive traces running in a second (Y) direction, usually orthogonal to the first direction, disposed on an opposed second face thereof. These three lower three layers (X and Y sensor traces, with PC board laminate in between) comprise the sensor matrix of a standard touchpad. A layer of compliant material is disposed over one of the faces of the substrate. An applique with a conductive coating on its back surface is affixed to the top surface of the compliant material.

According to a second embodiment of the present invention, a capacitive touch pad comprises a substrate material, such as a PC board type laminate material, having a plurality of first parallel conductive traces running in a first (X) direction disposed on a first face thereof, and a plurality of second parallel conductive traces running in a second (Y) direction, usually orthogonal to the first direction, disposed on an opposed second face thereof. These three lower three layers (X and Y sensor traces, with PC board laminate in between) comprise the sensor matrix of a standard touchpad. A layer of pressure-conductive material is disposed over one of the faces of the substrate. An applique with a conductive coating on its back surface is affixed to the top surface of the pressure conductive material.

According to a third embodiment of the present invention, a capacitive touch sensor suitable for stylus or light finger touch input comprises a rigid substrate material, such as a PC board laminate material having a conducting material disposed on one face thereof. A layer of pressure-conductive material is disposed over the conductive material on the substrate. A layer of flexible material, such as a mylar or polyimide material, having a plurality of first parallel conductive traces running in a first (X) direction disposed on a first face thereof, and a plurality of second parallel conductive traces running in a second (Y) direction, usually orthogonal to the first direction, disposed on an opposed second face thereof is disposed over the layer of pressure-conductive material. An applique is affixed to the top surface of the pressure conductive material to protect it.

According to a fourth embodiment of the present invention, a capacitive touch pad employs sensing traces in combination with a rugose material, i.e., one having at least one textured or corrugated surface. one such sensor may comprise a rigid material with a conducting surface over which is disposed a compliant material having at least one textured or corrugated surface. A flexible sensor matrix including conductive traces on opposing sides of a flexible membrane is disposed over the layer of rugose material. Another embodiment comprises such a flexible membrane sensor disposed on the textured or corrugated surface of a rugose compliant material. Yet another embodiment comprises a first set of conductive traces on a first substrate, a layer of compliant rugose material disposed over the first substrate, and a second set of conductive traces disposed on a second substrate located over the layer of rugose material.

An exemplary embodiment of this aspect of the invention comprises a substrate material, such as a PC board type laminate material, having a plurality of first parallel conductive traces running in a first (X) direction disposed on a first face thereof, and a plurality of second parallel conductive traces running in a second (Y) direction, usually orthogonal to the first direction, disposed on an opposed second face thereof. These three lower three layers (X and Y sensor traces, with PC board laminate in between) comprise the sensor matrix of a standard touchpad. An elastic sheet having at least one textured or a corrugated face is disposed over one of the faces of the substrate. An applique with a conductive coating on its back surface is affixed to the textured or corrugated surface of the elastic sheet and a dry adhesive is preferably disposed on the textured or corrugated surface of the elastic sheet to prevent adherence of the sheet to the applique.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

FIG. 1 is a cross sectional view of a capacitive sensor according to a first embodiment of the present invention employing a compliant material.

FIG. 2 is a cross sectional view of a capacitive sensor according to a second embodiment of the present invention employing a pressure-conductive material.

FIG. 3 is a cross sectional view of a capacitive sensor according to a third embodiment of the present invention.

FIG. 4 is a cross sectional view of a capacitive sensor according to a third embodiment of the present invention employing an air gap.

FIG. 5 is a cross sectional view of a first capacitive sensor according to a fourth embodiment of the present invention employing an elastic sheet having a textured or corrugated surface.

FIG. 6 is a cross sectional view of a second capacitive sensor according to a fourth embodiment of the present invention employing an elastic sheet having a textured or corrugated surface.

FIG. 7 is a cross sectional view of a third capacitive sensor according to a fourth embodiment of the present invention employing an elastic sheet having a textured or corrugated surface.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Those of ordinary skill in the art will realize that the following description of the present invention is illustrative only and not in any way limiting. Other embodiments of the invention will readily suggest themselves to such skilled persons.

According to the present invention, various embodiments of a novel touchpad sensor device are disclosed which extend the ability of established touchpad technology to work with a passive stylus. This new sensor design allows the use of any hard object as a stylus pointer (either conductive or non-conductive), while retaining all the present capacity to detect light finger touch.

The touchpad sensor design of the present invention may be used with electronics hardware and software systems such as those disclosed and claimed in co-pending application Serial No. 08/300,387, filed September 2, 1994, co-pending application serial No. 08/115,743, filed August 31, 1993, now United States Patent No. 5,374,787, and co-pending application serial No. 07/895,934, filed June 8, 1992, and necessitates no change to the existing electronics or software. The touchpad sensor of the present invention employs a novel use of materials in the

capacitive sensing matrix. Several alternative approaches based on the same basic principle are described.

In each of the embodiments of the invention described herein, the capacitive touchpad of the present invention employs a sensor matrix. In three of the disclosed embodiments, the sensor matrix comprises a thin substantially rigid layer of insulating material on which is disposed a grid composed of X conductive traces on a first face of the layer of insulating material, and Y traces on a second face of the layer of insulating material. This structure is typically implemented as ordinary copper traces on the top two layers of a multilayer printed circuit board. In the third embodiment of the present invention, a flexible sensor as a sensor matrix is implemented as conductive traces printed on opposing faces of a flexible substrate rather than a laminated circuit board. Flexible sensors have so far been made by two distinct methods. According to the first method, conductive ink is screen-printed on a mylar substrate. According to the second method, copper traces are etched on a polyimide substrate (flex circuit technology). These fabrication methods are illustrative and not limiting. As will be readily understood by persons of ordinary skill in the art, the X and Y conductive traces in all of the embodiments of the present invention are adapted to be electrically coupled to sensing circuitry, most typically via connection contacts located on edges of the touchpad in the X and Y planes. This feature of the present invention, which is found in all prior art touchpads, is so rudimentary and well understood that the drawing figures herein will not be unnecessarily cluttered by illustration of this feature, assumed to be well within the level of ordinary skill in the art.

For the purposes of this disclosure, a passive stylus is any object suitable for writing or drawing on a flat surface, A passive stylus does not contain any electronic components, and need not have any special electrical properties or be made of any special materials. The device must be somewhat pointed, easily held, and usable in the same manner as a pen.

Referring first to FIG. 1, a capacitive touchpad sensor 10 according to the present invention is shown in cross-sectional view. Capacitive touchpad sensor 10 includes a sensor matrix disposed on a substantially rigid substrate 12. Substrate 12 may be formed from a piece of standard printed circuit board material having a thickness in the range of from between about 0.025mm to about 0.1mm. A plurality of first conductive traces 14 running in a first (X) direction is disposed on a first face 16 of substrate 12. A plurality of second conductive traces 18 running in a second (Y) direction, typically orthogonal to the first direction, is disposed on a second face 20 of substrate 12. First and second conductive traces 14 and 18 may typically be formed by patterning and etching copper clad circuit board material as is well known in the art, or by equivalent known methods. Typical line spacing is in the range of between about 1.5mm and about 10mm.

A layer of compliant material 22 is disposed over the second face 20 and the plurality of second conductive traces 18. Compliant material 22 may have a thickness of between about 0.125 and about 1.25mm and may be a layer of compliant foam, which is a sheet of elastic material which deforms under pressure and springs back to its original shape when released. Many materials, some of which are not actually foams, exhibit this behavior, including various rubbers and silicone gels. Typical materials for use in this embodiment of the invention include, but are not limited to Sylgard silicone dielectric gel available from Dow Corning of Midland, MI, or Poron cellular urethane sheet available from Rogers Corporation of Rogers, CT. For purposes of this disclosure, all such materials will be referred to as compliant foams. Compliant foams can be manufactured over a wide range of stiffness, commonly quantified by a measure called durometer hardness. Materials with a durometer hardness in a range of from about 0.1 to about 10 are suitable for use in the present invention. Materials with a durometer hardness greater than 10 are unsuitable for this application.

A conductive layer 24 is disposed over the upper surface of the layer of compliant material 22 and a protective overlayer 26 is disposed over the upper surface of the conductive layer 24. As presently preferred, a mylar applique is employed as the protective overlayer 26. The protective overlayer 26 is the part of the capacitive touchpad sensor 10 actually touched and seen by the user. As such, it should preferably have a pleasing tactile and visual texture. The protective overlayer 26 is typically implemented as a sheet of textured polyester material, sold under the tradename Mylar, from about 0.1 mm to about 0.6 mm thick with an adhesive layer on its underside for affixing it to the top of the layer of compliant material 24. Mylar is generally transparent, so the back surface may either be painted to give a uniform appearance, or logos, lettering, or other patterns can be screen-printed on the back side in lieu of a uniform coat of paint. Those of ordinary skill in the art will realize that protective overlayer 26 need not be made out of mylar. Other materials like polycarbonate, sold under the tradename Lexan, also make suitable covers. In an embodiment employing polycarbonate, the sheet thickness is in a range of about 0.1 mm to about 0.6 mm.

Conductive layer 24 may be a very thin (less than 0.025mm) layer of metal or other conductor uniformly applied to a substrate. For example, it is possible to apply a conductive coating to a mylar applique by painting one surface of the mylar with conductive ink. A conductive coating can also be realized by sputtering a thin coating of metalization onto the mylar. By applying a conductive coating to a mylar applique, a flexible ground plane can be realized and conductive layer 24 and protective overlayer 26 may be thus combined such that they may be applied in a single assembly step.

The various layers of the capacitive touchpad sensor 10 of FIG. 1 are joined together using a suitable adhesive, such as Scotch brand core series 2-1300 0.25mm thick adhesive film. Those of ordinary skill in the art will recognize that other suitable adhesives may be used.

With no finger or stylus in contact with the surface of the capacitive touchpad sensor 10, the ground plane formed by the conductive layer 24 will appear to the sensor matrix as a uniform background capacitance. If sensing electronics like those described in United States Patent No. 5,374,787 or in co-pending application serial No. 08/300,387 are employed, background capacitance is ignored because of continuously self-calibrating measurement algorithms.

When a stylus 28 presses on the surface of capacitive touchpad sensor 10, the protective overlayer 26 and compliant material 22 will deform around the area of contact as shown in FIG. 1. This has the effect of pushing the conductive layer 24 closer to the first and second conductive traces 14 and 18 of the sensor matrix. The closer proximity of conductive material will increase the capacitance measured by the sensor matrix, and appear as a contact signal. The size of the contact signal is determined by the magnitude and shape of the deformation around the stylus 28. Wider, deeper deformations will yield a larger signal.

The size and shape of the deformation is controlled by several factors. First, the amount of force applied by the tip of stylus 28 affects the deformation. In addition, the stiffness (modulus) of the protective overlayer 26 is a factor. A stiffer surface will tend to form a wider, shallower deformation. Finally, the stiffness (durometer hardness) of the compliant material 22 affects the size and shape of the deformation. A stiffer material will tend to form a narrower, shallower deformation.

Ideally, under moderate stylus force the capacitive touchpad sensor 10 of the present invention should yield a signal strength comparable to a finger touch on an ordinary non-stylus touchpad sensor. By implication, the region of surface deformation created by moderate stylus force should be about the diameter of a finger contact patch (about 1 cm) and deep enough in the center to almost touch the conductive traces 18 of the sensor matrix. This requirement can theoretically be met by suitable selection of materials.

Stiffer complaint materials will always yield a smaller signal. Thus, it is desirable to select the most compliant possible material and then select a surface with a stiffness appropriate to give the desired deformation width. In practice, it is difficult to find compliant materials that yield satisfactory signals under moderate stylus pressure. Silicone gels are among the most compliant materials investigated, and even they do not give a satisfactory signal.

Those of ordinary skill in the art will recognize that the conductive coating on the bottom of the protective overlayer 26 effectively forms a ground plane over the top of the sensor matrix. While this necessary for the detection of a non-conductive stylus, as has been described above, it renders the pad insensitive to a light finger touch as a practical matter. A finger touching the protective overlayer 26 without any deformation is completely shielded from the sensor matrix by the conductive coating, hence will yield no signal whatsoever. If the finger applies heavy enough pressure to deform the surface, it will be detected in the same manner as the stylus 28.

So, while a sensor according to the embodiment of the invention depicted in FIG. 1 is theoretically suitable for detecting a stylus, it suffers from two significant drawbacks. First, as a practical matter, it is difficult to find a combination of a compliant material and a protective overlayer with the desired combination of material properties for producing a commercially-acceptable contact signal for both finger and stylus sensing.

Referring now to FIG. 2, a second embodiment of the present invention is shown in cross sectional view. The embodiment shown in FIG. 2 is in most respects identical to the embodiment depicted in FIG. 1 and thus corresponding structural elements of the two embodiments will be assigned like reference numerals in the figures for ease of comparison by persons of ordinary skill in the art. Furthermore, the thicknesses of particular layers of materials in the embodiment of FIG. 2 which correspond to layers in the embodiment of FIG. 1 may have the same thicknesses as the layers in the embodiment of FIG. 1.

Capacitive touchpad sensor 30 of FIG. 2 includes a sensor matrix disposed on a substantially rigid substrate 12. A plurality of first conductive traces 14 running in a first (X) direction is disposed on a first face 16 of substrate 12. A plurality of second conductive traces 18 running in a second (Y) direction, typically orthogonal to the first direction, is disposed on a second face 20 of substrate 12. In this respect, the sensor matrix of this embodiment of the invention is identical to that shown in FIG. 1.

The first limitation of the sensor shown in Figure 1 (difficulty in finding materials that yield enough signal) can be addressed by using a layer of pressure-conductive material 32 in place of the compliant material 22 of the embodiment of FIG. 1.

Pressure-conductive material 32 may be formed from a class of compliant foam materials specially designed to have unusual electrical properties. In the present invention, thicknesses from between about 0.125 and about 1.25 mm may be employed. Under normal conditions, the sheet is an electrical insulator. When pressure is applied which tends to compress the sheet in thickness, the material becomes conductive (less resistive) in the compressed region. Material called Pressure

Sensing Membrane, presently under development by 3M Corporation is suitable for this purpose. This material is only conductive in the Z (thickness) axis when compressed. Other materials conduct homogeneously when compressed. Either type of material is suitable for this application.

For use in the present invention, sheet thicknesses between 0.125 mm and 1.25 mm is best for the layer of pressure-conductive material 32. Since pressure conductive materials create a capacitive effect electrically, rather than through mechanical deformation, the durometer hardness of the material is not particularly important.

A conductive layer 24 is disposed over the upper surface of the layer of pressure conductive material 32 and a protective overlayer 26 is disposed over the upper surface of the conductive layer 24. These layers may be identical to their counterparts in the embodiment of FIG. 1.

As in the embodiment of FIG. 1, with no stylus or finger on the pad, the pressure-conductive material 32 of capacitive touchpad 30 of FIG. 2 will be an insulator separating the conductive traces 14 and 18 of the sensor matrix from the conductive coating 24, which will appear as a uniform background capacitance. When a stylus 28 applies pressure to the surface, the protective overlayer 26 will be deformed, bringing the conductive layer 24 somewhat closer to the conductive traces 14 and 18 of the sensor matrix. But, more importantly, the pressure-conductive film will be compressed in a region around the tip of the stylus 28. Thus, the region of pressure-conductive film near the stylus 28 will become a conductive object in direct contact with the surface of the sensor matrix. The capacitance of the nearby conductive traces 14 and 18 of the sensor matrix will be increased somewhat by the nearer physical proximity of the conductive layer 24, but much more by the immediate electrical proximity of the conductive region formed by the pressure-conductive material 32. In effect, the formation of a conductive zone by the pressure-conductive material 32 brings the ground plane formed by the conductive layer 24 closer to the conductive traces 14 and 18 of the sensor matrix electrically, rather than physically.

Since physical deformation is no longer the primary mechanism for sensing the stylus, the stiffness of the pressure-conductive material 32 is not as important as it is in the embodiment of FIG. 1. Stylus touchpad sensors 30 with suitable sensitivity have been constructed in this manner.

This touchpad 30 of FIG. 2 suffers from the same relative insensitivity to a light finger touch as does the embodiment described with reference to FIG. 1. The conductive traces 14 and 18 of the sensor matrix are still shielded from the finger by the conductive layer 24.

Referring now to FIG. 3, a capacitive touchpad sensor 40 according to a third embodiment of the present invention is shown in cross sectional view. Touchpad sensor 40 is suitable for detecting either a light finger touch or a non-conductive (or, for that matter, conductive) stylus.

Capacitive touchpad sensor 40 employs a flexible sensor matrix as previously described. A flexible sensor matrix is implemented as conductive traces 14 and 18 disposed on opposing faces 16 and 20 of a flexible substrate 42. According to the present invention method, conductive ink traces screen-printed on a mylar substrate 42 form conductive traces 14 and 18, or copper lines forming conductive traces 14 and 18 are etched on a flexible polyimide substrate 42.

As may be seen from an examination of FIG. 3, touchpad sensor 40 is somewhat inverted from the sensors described with reference to FIGS. 1 and 2. That is, a rigid substrate material 44, formed from a material such as a piece of PC board material has a conductive layer 46 disposed on its upper surface forming a ground plane. A layer of compliant material 22 like that disclosed in the embodiment of FIG. 1, is disposed over the surface of conductive layer 46. The sensor matrix comprising the flexible substrate 42 and conductive traces 14 and 18 is disposed over the surface of compliant material 22. Finally, protective overlayer 26 is disposed over the upper surface 20 of the flexible substrate and conductive traces 18. No conductive layer is necessary under protective overlayer 26 as was necessary in the embodiments of FIGS. 1 and 2.

Since the sensor matrix comprising flexible substrate 42 and conductive traces 14 and 18 is now immediately beneath the protective overlayer 26, the sensor matrix is no longer shielded from finger capacitance as it was in the embodiments of FIGS. 1 and 2. Therefore, the touchpad sensor 40 of FIG. 3 will have the same sensitivity to a light finger touch as a conventional capacitive touchpad implemented on a PC board. In either case, the conductive traces 14 and 18 of the sensor matrix are separated from the finger only by the thickness of the protective overlayer 26.

When a stylus 28 presses on the surface of the touchpad 40, the protective overlayer 26, flexible substrate 42, and compliant material 22 will all deform in the region of the tip of the stylus 28. Whereas, in the touchpads 10 and 30 of FIGS. 1 and 2, respectively, this had the effect of bringing a flexible ground plane closer to a fixed sensor matrix, it now has the opposite effect. The flexible sensor matrix comprising the flexible substrate 42 and conductive traces 14 and 18 is brought closer to a fixed ground plane comprising conductive layer 46. In both structures. the result is an increase in the capacitance of the sensor matrix and, thus, the capacitive detection of the tip of the stylus 28.

As previously noted, replacing the compliant material 22 of the embodiment of FIG. 1 with the pressure-conductive material of the embodiment of FIG. 2 renders the touchpad 30 of FIG. 2

far more sensitive to a stylus. This same principle applies equally well to the touchpad 40 of FIG. 3. If layer 22 is replaced with a layer of pressure-conductive material 32 (reference numeral shown in parenthesis in FIG. 3), the resultant structure is sensitive to either a light finger touch or a passive stylus.

For a conventional capacitive sensor, the traces of one of the two sets of conductive traces 14 or 18 (the one on top) must necessarily be closer to the finger than the other set. This does not impede the operation of the sensor, but it is well known that signals measured from the top axis are noticeably larger than signals measured from the bottom axis.

This parasitic effect can be used to advantage in the structure shown in FIG. 3. By noting which of the two sets of traces has a stronger contact signal, software can determine whether the sensor is being activated by a stylus or a finger. If a finger is creating the signal, the capacitance is applied to the top of the structure, and the top axis will have a bigger signal. If a stylus is used, the capacitive effect is introduced underneath the sensor, and the bottom axis will have a larger signal. The ability to detect the difference between pen and finger activation is useful, for example, in selecting between absolute and relative positioning modes in a paint program. This information is useful to software applications in general.

Those of ordinary skill in the art will recognize that the substrate 44 supporting the ground plane of conductive layer 46 underneath the compliant material 22 need not be implemented as a flat rigid structure such as a PC board. It could alternatively be implemented as a conductive coating applied to a flexible substrate. In such an embodiment, the sensor assembly could then be applied to any curved hard surface.

Alternative implementations of the present invention are possible. In the touchpads shown in FIGS. 1 and 3, the compliant material can be replaced by an air gap. This gap can be formed by suspending the protective overlayer 26 (and the flexible substrate 42 of FIG. 3) on spacers around the periphery of the touchpad area. If the space between the Flexible Sensor and the ground plane is a gap rather than layer of compliant material, it is much easier for moderate pen pressure to create a large signal. Such an airgap touchpad sensor can be easily constructed so that even moderate stylus pressure forces the flexible substrate into direct contact with the underlying ground plane.

Referring now to FIG. 4, a cross sectional view of a capacitive touchpad sensor employing such an airgap is shown. Capacitive touchpad sensor 50 is formed on a rigid substrate material 52, formed from a material such as a piece of PC board material has a conductive layer 54 disposed on its upper surface forming a ground plane. A frame member 56 is formed over

substrate 52 (and optionally over conductive layer 54 around the periphery of capacitive touchpad sensor 50 and defines an air gap region 58.

A composite structure comprising a flexible substrate 60 having a plurality of first spaced-apart parallel conductive lines 62 running in a first direction disposed on a first face and a plurality of second spaced-apart parallel conductive lines 64 running in a second direction perpendicular to the first direction disposed on a second face is mounted on frame 56 over air gap region 58.

There are several advantages to capacitive touchpad sensor 50. First, there is no need for compliant material, pressure-conductive film or other special materials. In addition, the capacitive touchpad sensor 50 of FIG. 4 will yield a large signal from moderate stylus pressure.

Unfortunately, as seen from FIG. 4, the shape of the depression formed by a stylus 28 on capacitive touchpad sensor 50 is not the symmetric depression shown for the embodiments of FIGS. 1-3 herein. Instead, the surface will be deformed in the manner of an inverted tent, with the "peak" of the tent being the tip of the stylus 28, and the "base" of the tent being the frame 56 around the periphery of the pad.

This tent deformation will influence the capacitance of the sensor matrix over its entire area, not just in the region of the stylus tip 28. Many present touchpads report position as the centroid of the capacitive profile on their surfaces. The tent deformation created by a stylus on an airgap sensor such as capacitive touchpad sensor 50 can (and frequently does) have a centroid which does not correspond to the point of contact. This may lead to undesirable artifacts when an airgap sensor is used as a pointing device.

There are two possible solutions for the distortion of the capacitive centroid caused by tent deformation. First, as will be appreciated by those of ordinary skill in the art, a peak-finding rather than a centroid-finding approach can be used to determine position. Alternately, using software to remap the position and pressure reported by the sensor can correct for the centroid distortion after-the-fact.

According to another aspect of the present invention, a capacitive sensor comprises sets of spaced apart conductive traces in combination with a compliant layer of a rugose material, i.e., one having at least one textured or corrugated surface. Such a sensor may take any one of a numerous number of forms. For example, one embodiment may comprise a rigid material with a conducting surface over which is disposed a compliant material having at least one textured or corrugated surface. A flexible sensor matrix, such as the one shown in the embodiment of FIG. 3 including traces 14 and 18 on opposing sides of flexible membrane 42 is disposed over the layer of rugose

material. Another embodiment comprises the flexible membrane sensor of FIG. 3 disposed on the textured or corrugated surface of a rugose compliant material. Yet another embodiment comprises a first set of conductive traces on a first substrate, a layer of compliant rugose material disposed over the first substrate, and a second set of conductive traces disposed on a second substrate located over the layer of rugose material.

Rugose materials, such as textured or corrugated elastic sheets work so well in the capacitive sensor of the present invention because of the sudden change in dielectric constant that occurs when the gaps between the surface of the sheet and the surrounding material (the sensor matrix and the conductive coating) collapse. Very little force is required to deform the texture and collapse the gaps, increasing the area of contact with the surrounding material and causing a sharp increase in the local dielectric constant. Those of ordinary skill in the art will appreciate that such a sensor will even function when both sets of traces are on the same side of the layer of rugose material and no conductive layer exists on the other side of the layer of rugose material, since the deformation of the rugose material significantly affects the transcapacitance of the entire structure.

Referring now to FIG. 5, a first capacitive sensor 70 according to this aspect of the present invention is shown in cross-sectional view. Capacitive touchpad sensor 70 includes a sensor matrix disposed on a substantially rigid substrate 12. Substrate 12 may be formed from a piece of standard printed circuit board material having a thickness in the range of from between about 0.025mm to about 0.1mm. A plurality of first conductive traces 14 running in a first (X) direction is disposed on a first face 16 of substrate 12. A plurality of second conductive traces 18 running in a second (Y) direction, typically orthogonal to the first direction, is disposed on a second face 20 of substrate 12. First and second conductive traces 14 and 18 may typically be formed by patterning and etching copper clad circuit board material as is well known in the art, or by equivalent known methods. Typical line spacing is in the range of between about 1.5mm and about 10mm.

Those of ordinary skill in the art will recognize that the embodiment of FIG. 5 closely resembles the embodiment disclosed with respect to FIG. 1. By simply replacing the layer compliant foam 22 of FIG. 1 with a layer of elastic material 72 having at least one textured or corrugated face 74, a touchpad can be constructed with a sensitivity to light finger touch approaching or exceeding that of a traditional capacitive pad, and with a sensitivity to styluses far exceeding any of the previously described schemes.

For the purposes of this disclosure, a textured layer of elastic material may be a sheet of compliant material with a vertically relieved surface texture (e.g., grooves or bumps 76) applied to one or both sides. As presently preferred, the depth of the texture should be in the range of from

about 0.025mm to about 2.0mm and the overall sheet thickness should be between about 0.050mm and about 3mm. When the textured elastic sheet is placed in resting contact with any flat plate, only the tips of its textured surface (e.g. the high points of the bumps 76) will contact the plate as shown in the regions close to the edges of FIG. 5. If the sheet is pressed against the plate as illustrated in FIG. 5 by stylus 28, the surface texture should "crush" in such a way that the area of contact with the plate increases. This increase in contact area with pressure is the operative property of a textured or corrugated elastic sheet.

A textured elastic sheet 72 can be made from virtually any rubber or elastic polymer material. Silicone rubbers, such as RTV-1000B material available from Circle-K Products of Torrance, California, are particularly suitable for this application, although Neoprene (available from the DuPont corporation), urethane, and many other types of elastic polymers are also suitable. The surface texture can be applied to the material through any one of several well-known processes, including molding, rolling, or milling.

In this embodiment of the present invention, it can be useful in to increase the effective dielectric constant of the textured elastic sheet 72 by impregnating the polymer with conductive particles. For the RTV-1000B silicone rubber material obtained from Circle-K Products, this is best accomplished by mixing graphite powder with the liquid rubber before it cures.

For the purposes of the present invention, a corrugated elastic sheet 72 is a non-flat sheet of compliant material with some degree of waviness or ripples permanently molded into its structure. The molded corrugations should be uniform in two dimensions. For example, "egg crate", "waffle", and "honeycomb" patterns with a characteristic spatial frequency of $5mm^2$ - $0.5mm^2$ are suitable for this application. A corrugated elastic sheet 72 can be formed from the same polymers used to make a textured elastic sheet described above. The material thickness should be in the range of from about 0.025mm to about 0.5mm, and the waves should be between about 0.025mm and about 2mm deep. When a corrugated elastic sheet 72 is placed in resting contact with a flat plate, only the high points 76 of the corrugated pattern will contact the plate. As the sheet is pressed against the plate, the corrugated elastic sheet 72 will deform in such a way that the surface area of contact increases with pressure. This increase of contact area with pressure is the operative property of a corrugated elastic sheet in this application.

A conductive layer 24 is disposed over the upper surface of the textured or corrugated sheet 72 and a protective overlayer 26 is disposed over the upper surface of the conductive layer 24. As in the embodiment of FIG. 1, a mylar applique is preferred as the protective overlayer 26. The protective overlayer 26 is the part of the capacitive touchpad sensor 10 actually touched and seen by the user.

For proper performance as a pointing device, it is important that the textured features or corrugations rapidly "spring back" to their original shape when the pressure is removed, lest a "trail" of persistent elevated dielectric follow the stylus or finger. Thus, it is important that the textured or corrugated sheet not adhere to the adjacent layers. When using a sheet made from silicone rubber or other sticky material, it is necessary to apply a dry lubricant between the sheet and the adjacent layer to prevent adhesion. A dry lubricant is a material which prevents adhesion between two otherwise sticky surfaces. In this application, it is desirable to prevent adhesion between, for example, a textured elastic sheet and a mylar applique. A dry lubricant such as Miller Stephenson MS-122 Release Agent, available from the Miller-Stephenson Chemical Company of Danbury, Connecticut, is an example of a dry lubricant suitable for the purposes of the present invention.

A touchpad implemented with the structure of FIG. 5 (as well as that of FIG. 1) has an important difference from a traditional pad: the sensor matrix is completely shielded from the surrounding electrical and capacitive environment by the conductive coating 24 on the underside of the mylar applique 26. Thus, the sensor is entirely isolated from any influence beyond the conductive coating, including electrical noise in the environment, moisture on the surface of the pad, and electrostatic discharge to the surface of the pad. In fact, the isolation from moisture is so complete that the pad, if properly sealed, can be operated under water with no performance degradation.

Referring now to FIG. 6, a first capacitive sensor 80 according to this aspect of the present invention is shown in cross-sectional view. Capacitive sensor 80 of FIG. 6 is similar to that shown in FIG. 3 in that it is supported on rigid substrate 44 having a conductive layer 46 on one surface. The layer of textured or corrugated compliant material 72 is disposed over the substrate 44 and conductive layer 46 and a flexible sensor like that of FIG. 3 is disposed over the layer 72. Conductive layer 46 is optional and is not required, since the change in dielectric constant due to deformation of the surface of the textured or corrugated material will affect the transcapacitance of the flexible matrix even without the presence of the conductive layer 46.

Referring now to FIG. 7, a first capacitive sensor 90 according to this aspect of the present invention is shown in cross-sectional view. The sensor matrix in capacitive sensor 90 of FIG. 7 straddles the textured or corrugated compliant material. First substrate 12 carries first set of conductive lines 18 and flexible substrate 42 carries second set of conductive traces 14. The compliant layer of textured or corrugated material lies between the two sets of conductive traces.

The embodiments of FIGS. 6 and 7 operate according to the same principles as the embodiment of FIG. 5. The change in dielectric constant caused by deformation of the textured or corrugated surface of layer 72 causes capacitance changes which may be easily sensed.

While embodiments and applications of this invention have been shown and described, it would be apparent to those skilled in the art that many more modifications than mentioned above are possible without departing from the inventive concepts herein. The invention, therefore, is not to be restricted except in the spirit of the appended claims.

What is claimed is:

1. A capacitive sensor comprising:

a rigid substrate having first and second opposing faces;

a plurality of first parallel conductive traces running in a first direction disposed on said first face of said substrate;

a plurality of second parallel conductive traces running in a second direction orthogonal to said first direction, disposed on said second face of said substrate;

a layer of compliant material disposed over one of said first and second parallel conductive traces, said layer of compliant material having at least one textured surface;

a layer of conducting material disposed on an upper surface of said layer of compliant material; and

a protective layer disposed on an upper surface of said layer of conducting material.

2. A capacitive sensor as recited in claim 1, wherein said layer of compliant material comprises an elastic polymer material.

3. A capacitive sensor as recited in claim 1, wherein said layer of compliant material comprises silicone rubber.

4. A capacitive sensor as recited in claim 1, wherein said at least one textured surface of said layer of compliant material has a texture depth of between about 0.025mm and about 2.0mm

5. A capacitive sensor as recited in claim 1, wherein said layer of compliant material has a thickness in a range from about 0.05mm to about 3mm.

6. A capacitive sensor as recited in claim 1, wherein said protective layer comprises a sheet of polycarbonate having a thickness in a range from about .1 mm to about .6 mm.

7. A capacitive sensor as recited in claim 6, wherein said layer of conducting material comprises a conductive coating disposed on a bottom surface of said sheet of polycarbonate.

8. A capacitive sensor as recited in claim 1 wherein said layer of compliant material has two textured surfaces.

9. A capacitive sensor comprising:

a rigid substrate having first and second opposing faces;

a plurality of first parallel conductive traces running in a first direction disposed on said first face of said substrate;

a plurality of second parallel conductive traces running in a second direction orthogonal to said first direction, disposed on said second face of said substrate;

a layer of compliant material disposed over one of said first and second parallel conductive traces, said layer of compliant material having at least one corrugated surface;

a layer of conducting material disposed on an upper surface of said layer of compliant material; and

a protective layer disposed on an upper surface of said layer of conducting material.

10. A capacitive sensor as recited in claim 9, wherein said layer of compliant material comprises an elastic polymer material.

11. A capacitive sensor as recited in claim 9, wherein said layer of compliant material comprises silicone rubber.

12. A capacitive sensor as recited in claim 9, wherein said at least one corrugated surface of said layer of compliant material has a corrugation depth of between about 0.025mm and about 2.0mm

13. A capacitive sensor as recited in claim 9, wherein said layer of compliant material has a thickness in a range from about 0.025mm to about 2mm.

14. A capacitive sensor as recited in claim 9, wherein said protective layer comprises a sheet of polycarbonate having a thickness in a range from about .1 mm to about .6 mm.

15. A capacitive sensor as recited in claim 16, wherein said layer of conducting material comprises a conductive coating disposed on a bottom surface of said sheet of polycarbonate.

16. A capacitive sensor as recited in claim 9 wherein said layer of compliant material has two corrugated surfaces.

17. A capacitive sensor comprising first and second sets of conductive traces and a compliant rugose material having a rugose surface located proximate to the first and second sets of conductive traces whereby deformation of said rugose surface causes a change in dielectric constant of said rugose material.

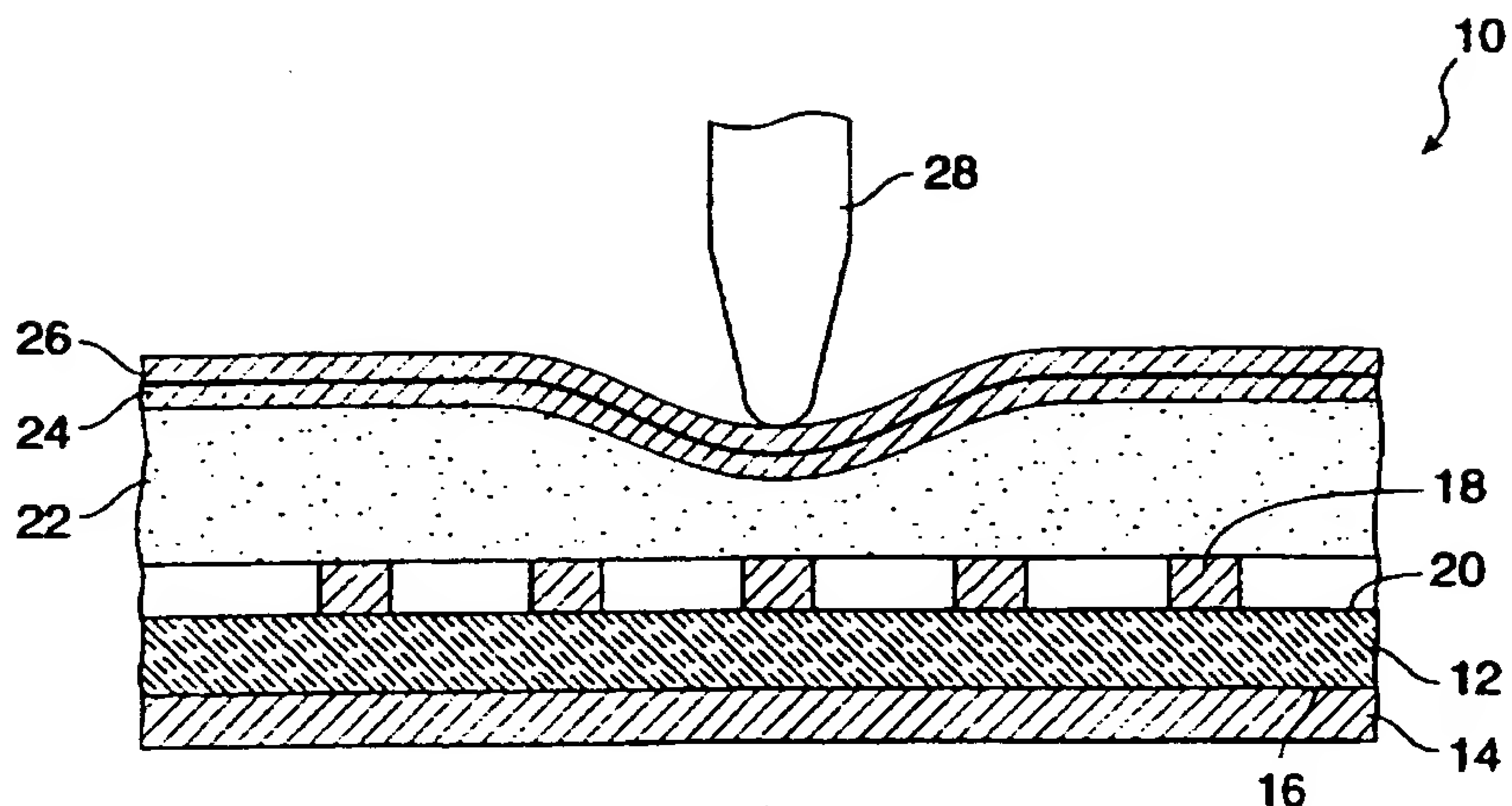

FIG. 1

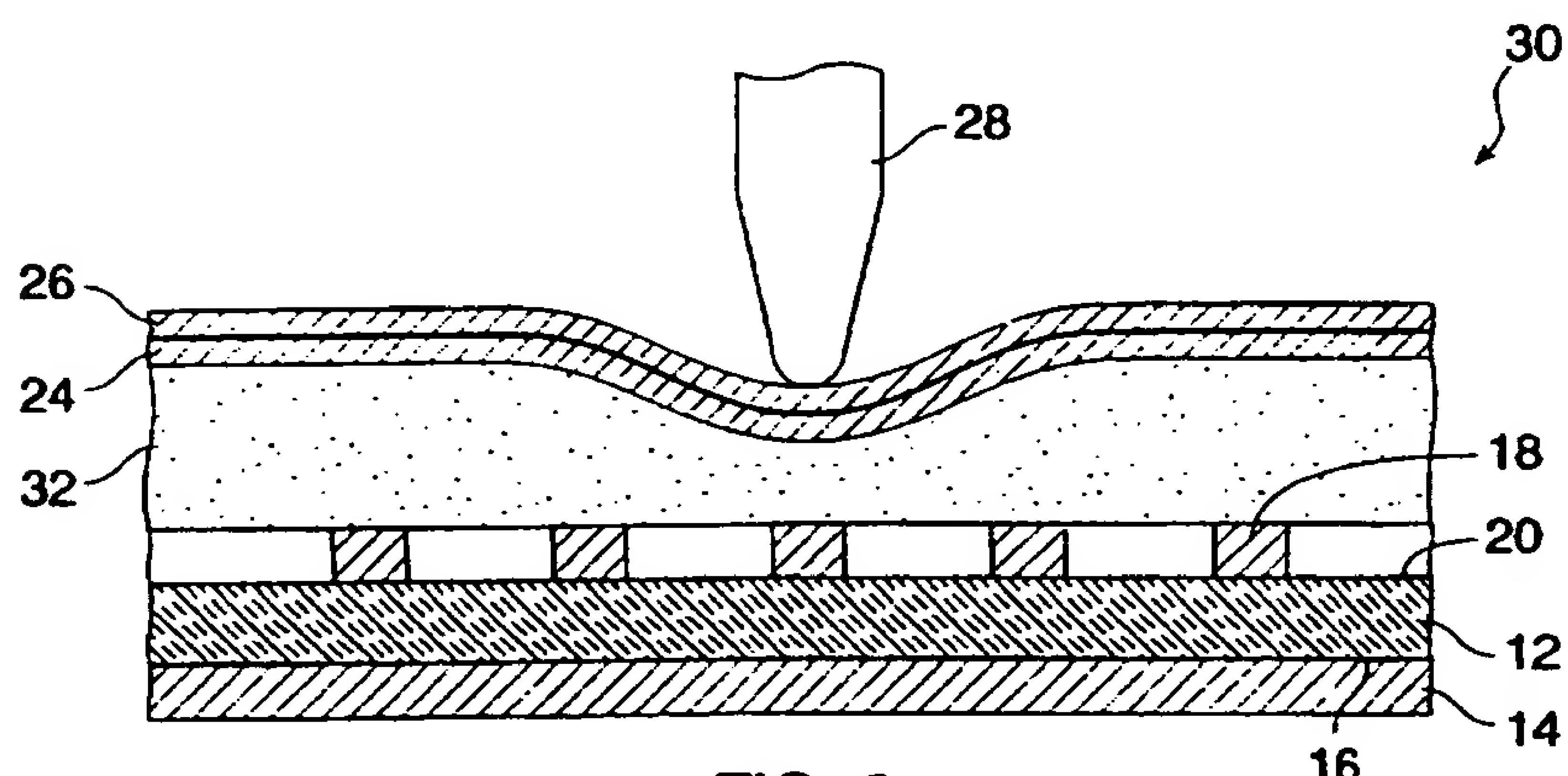

FIG. 2

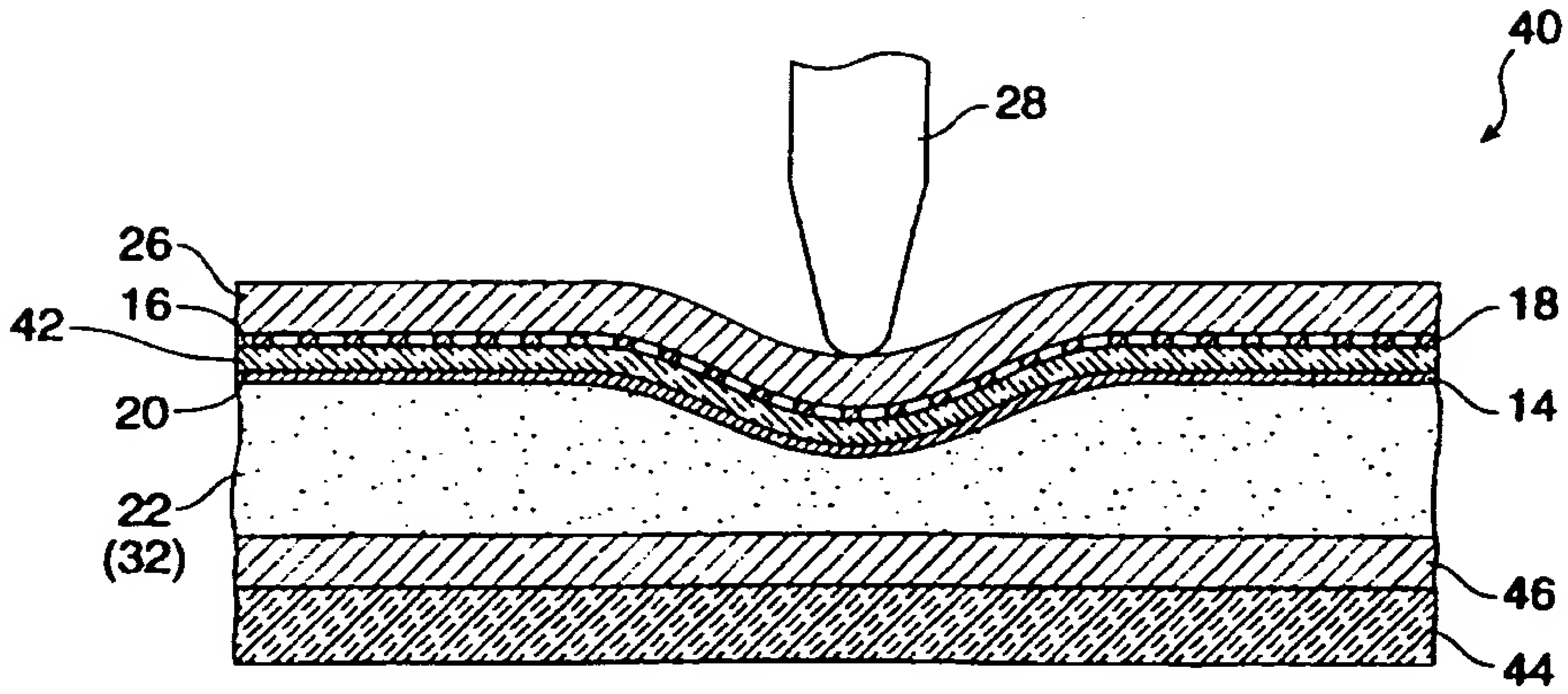

FIG. 3

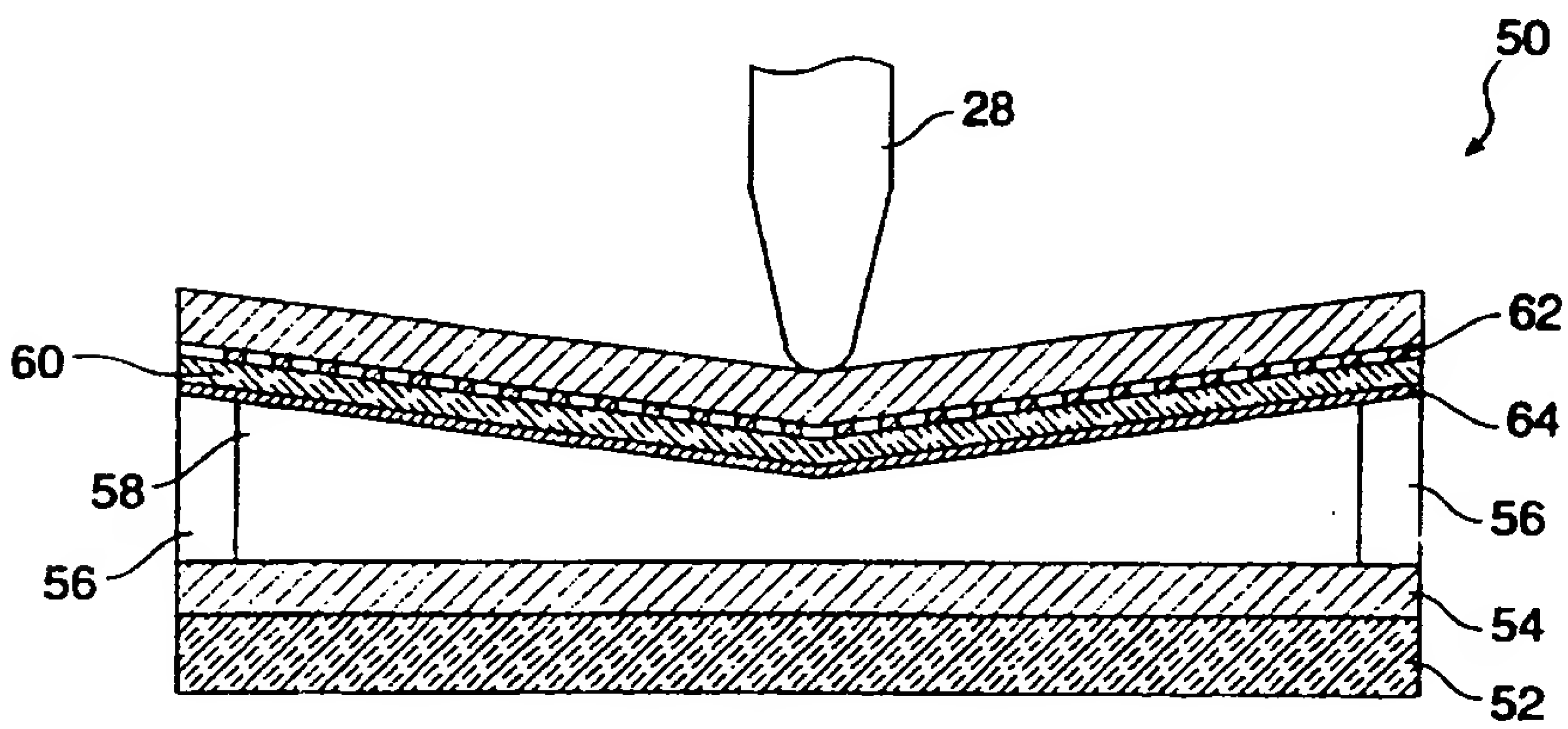

FIG. 4

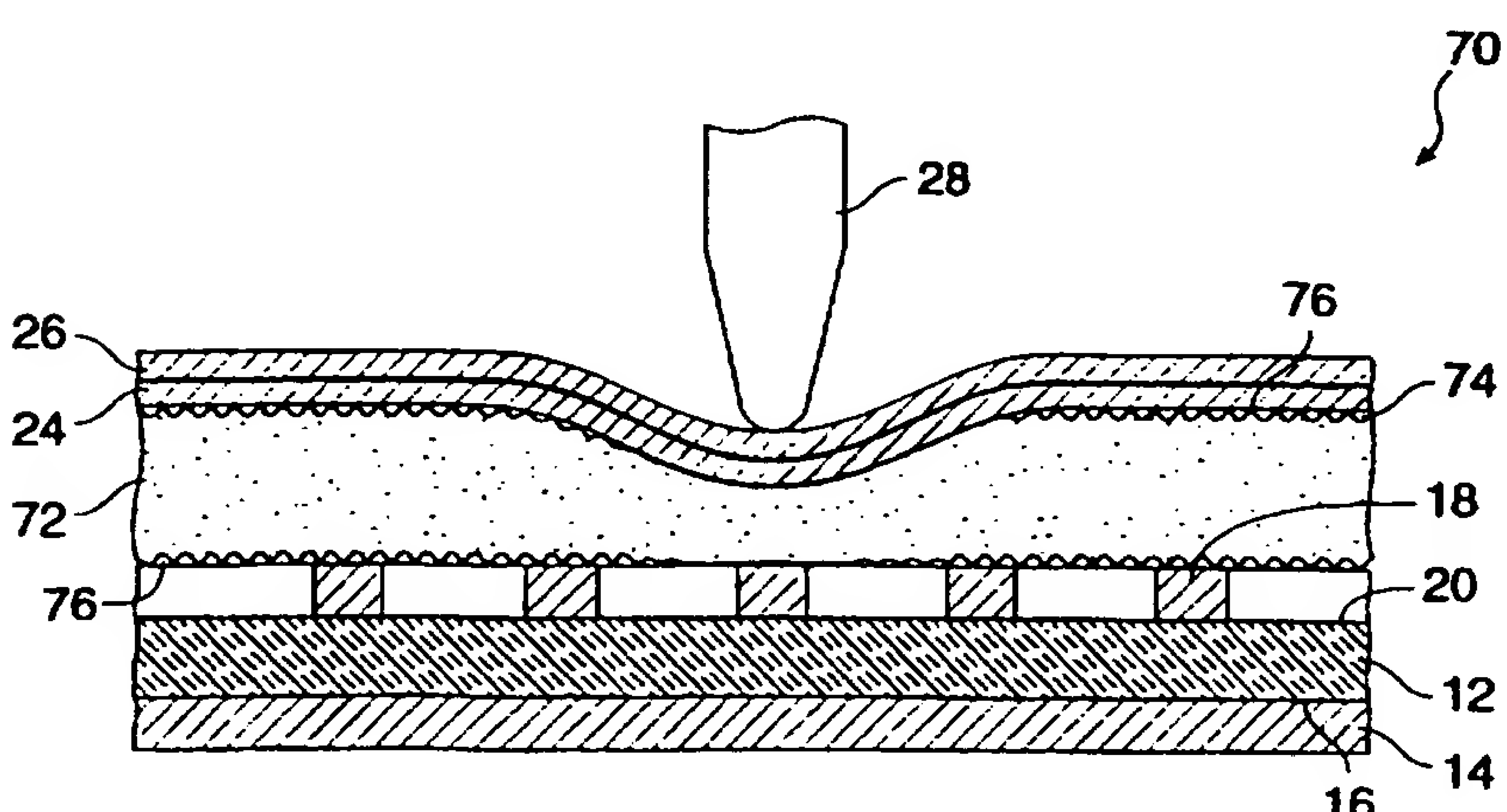

FIG. 5

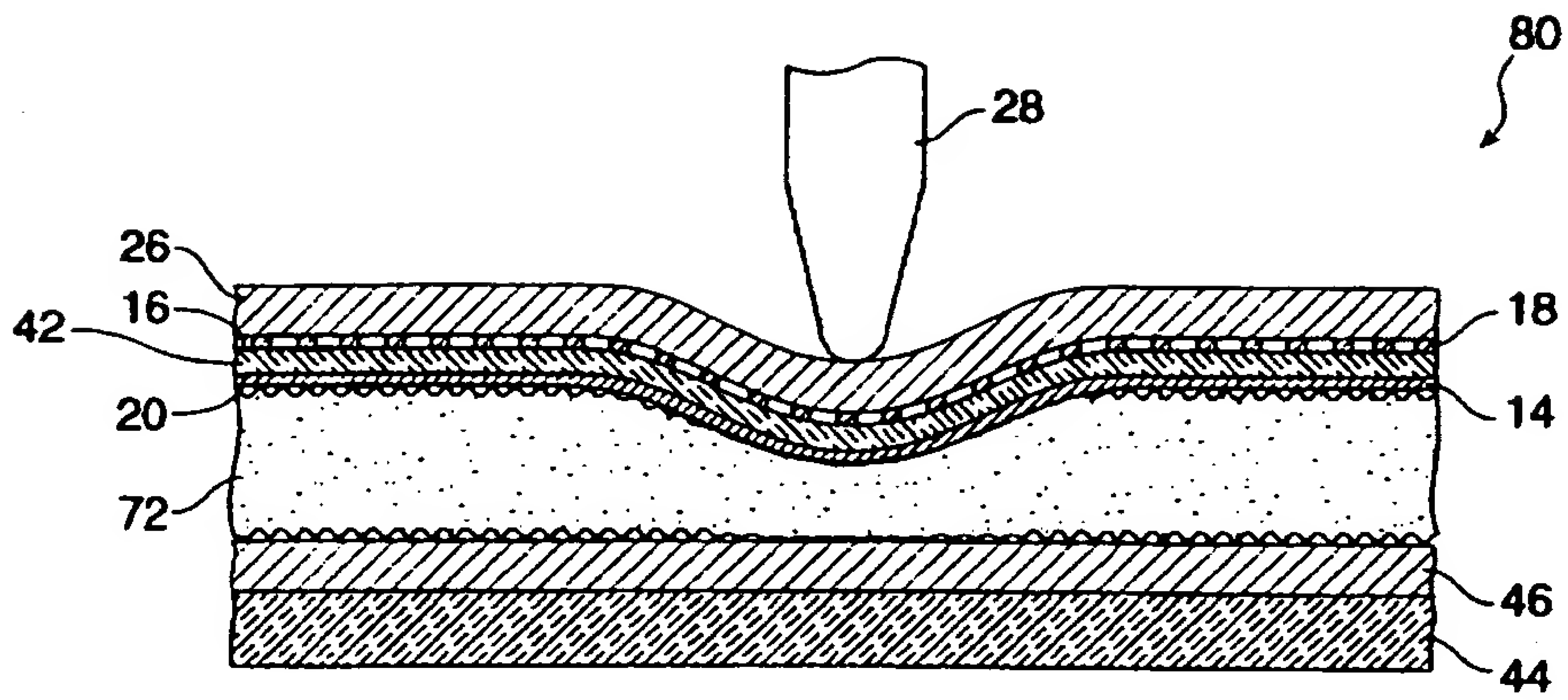

FIG. 6

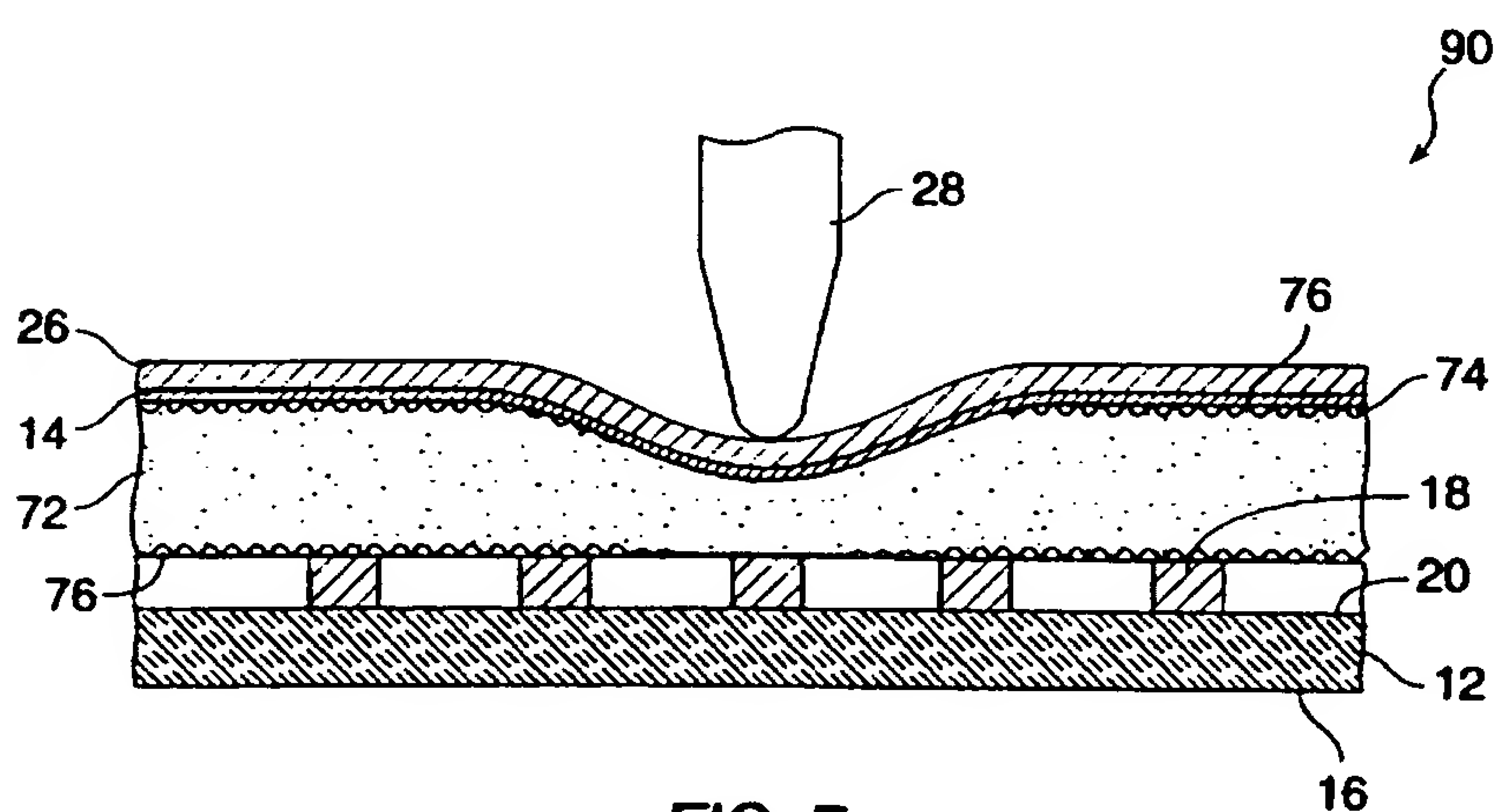

FIG. 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/17859

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G06K11/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 288 665 A (SAMSUNG DISPLAY DEVICES CO LTD) 25 October 1995 see page 1, line 25 - page 2, line 17 see page 7, line 11 - page 9, line 5; figures 3-7 ---	1-17
X	US 4 526 043 A (BOIE ROBERT A ET AL) 2 July 1985 see column 3, line 13 - column 4, line 41; figures 1,2 ---	1-17
A	US 5 386 219 A (GREANIAS EVON C ET AL) 31 January 1995 see column 7, line 57 - column 8, line 18 see column 16, line 57 - column 18, line 37; figures 5-8 --- -/--	1-17

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
6 March 1997	17.03.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Nygren, P

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/17859

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 516 112 A (CHEN CHEE G) 7 May 1985 see the whole document -----	1-17

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Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 96/17859

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